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Literature study: The Efficiency of Aquaponic Systems in Fish and Crop Production: A Case Study in an Urban Environment

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ABSTRACT

Aquaponics is a cultivation system that integrates fish cultivation with plant cultivation in a mutualistic symbiotic manner. This system uses wastewater from fish as nutrients for plants, while the plants clean the water through root filtration. This paper aims to analyze the efficiency of aquaponic systems in fish and plant production, with a focus on case studies conducted in urban environments. The analysis results show that the aquaponics system in fish and plant production in urban environments can achieve a high level of efficiency. In terms of water use, this system is more efficient than conventional cultivation methods because water can be reused and not wasted. Efficiency in energy use is also visible because aquaponic systems reduce energy requirements for water circulation and environmental maintenance of plants. In addition, analysis of the nutritional efficiency of the aquaponic system shows that nutrients from fish waste can be utilized optimally by plants so that the use of additional fertilizer can be reduced. This has positive implications in terms of cost savings and reduced environmental impact. This case study shows that aquaponic systems are a potential solution to increase the efficiency of fish and plant production, especially in urban environments where land and resources are limited. Apart from production efficiency, this system also has additional benefits, such as local food production, reduction of organic waste, and development of sustainable agriculture.

INTRODUCTION

The aquaponics system is a system that combines fish and plant cultivation in one integrated system (Garnida, 2023). This system takes advantage of the symbiotic relationship between fish and plants, where nutrient-rich water from the fish pond is used as a source of nutrition for the plants while the plants clean the water, which will return to the fish pond. The uniqueness of this aquaponic system has attracted attention as a sustainable and efficient alternative for food production in urban environments (Amiin et al., 2022). One of the advantages of an aquaponic system is its high efficiency in resource use. In conventional cultivation, water and nutrients are often wasted and require significant inputs. However, water and nutrients can be recycled between fish and plants in an aquaponic system, reducing the need for fresh water and additional fertilizer (Azhari

& Tomasoa, 2018). Thus, aquaponic systems can produce fish and plants using resources more efficiently, essential in resource-limited urban environments.

In recent years, several studies and case studies have been conducted to analyze the efficiency of aquaponic systems in fish and plant production in urban environments. Research conducted includes water quality in aquaponic systems (Dauhan et al., 2014; Setijaningsih et al., 2015; Farida et al., 2017; Putra et al., 2018; Darwis et al., 2019; Handayani et al., 2020; Setiawan et al., 2024); growth of fish and plants in aquaponic systems (Mulqan et al., 2017; Azhari and Tomasoa, 2018; Rahmadhani et al., 2020; Pratopo and Thoriq, 2021); as well as the role of aquaponics as a form of food security and nutritional fulfillment for the community (Perwitasari and Amani, 2019; Setiyaningsih et al., 2021; Fauza et al., 2021; Hidayatulloh et al., 2022). These studies aim to understand the benefits and challenges associated with implementing aquaponic systems and measure the efficiency level in food production. The research results provide a better understanding of aquaponic systems' potential and limitations in urban environments. Research on analyzing the efficiency of aquaponic systems in urban environments by monitoring various parameters, such as fish feed conversion, plant growth, water quality, and energy input, has been widely carried out. This research shows that the aquaponic system can achieve a high level of efficiency in fish and plant production compared to conventional separate cultivation systems. Aquaponic systems have better fish feed conversion, faster plant growth, and produce good water quality. In addition, the energy input required by an aquaponic system is also lower. These findings provide evidence that aquaponic systems have the potential to be an efficient solution in meeting food needs in urban environments. However, there are several challenges, such as proper nutritional management, maintenance of water quality, and disease control. Besides that, economic and social aspects also need to be considered for the sustainability of aquaponic systems on a broader scale. Therefore, analyzing the efficiency of aquaponic systems in the context of urban environments is essential to understanding the potential and constraints associated with their implementation.

In the Indonesian context, where the urban population continues to grow, sustainable aquaponic systems can be an essential solution to facing food challenges and meeting local food needs. Case studies in urban environments can provide valuable insight into how aquaponics systems can be implemented efficiently, making the most of limited space and resources. Analysis of the efficiency of aquaponic systems in fish and plant production in urban environments can provide a solid scientific basis for developing and improving the implementation and benefits of these systems in urban contexts.

Aquaponics System

Aquaponics is a cultivation system that integrates aquaculture farming (fish cultivation) and hydroponics (plant cultivation without soil) in one mutually supporting system (Anjani & Kusdarwati, 2017). In an aquaponics system, water containing nutrients from fish waste provide nutrients for plants growing in a non-soil growing medium while the plants cleanse fish wastewater. This concept is based on a symbiotic relationship between fish, plants, and bacteria, which play a role in converting fish waste into nutrients that plants can absorb. This definition of aquaponics shows that this system focuses on the integration and symbiotic relationship between fish and plant cultivation, with water as the primary medium to provide nutrients and regulate the optimal environment for the growth of both organisms.

An aquaponic system's working principle is "a continuous cycle of nutrients between fish, bacteria, and plants." Fish waste containing ammonia is converted by nitrifying bacteria into nitrate compounds, which plants can absorb as nutrients (Asis et al., 2017). Plants take these nutrients from the water, clean the water of fish waste, and return cleaner water to the pond. According to Dauhan & Efendi (2014), the working principle of the aquaponic system can also be explained as "environmental integrity related to the sustainability of food production." Organic waste produced by fish is used as a source of nutrients for plant growth, thereby reducing environmental impacts and maximizing resource utilization efficiency. In an aquaponic system, there is a symbiotic relationship between fish, plants, and bacteria. Fish provide nutrients to plants through waste, while plants clean fish wastewater. Nitrifying bacteria are essential in converting fish waste into nitrate compounds that plants can absorb. In this system, all components are interdependent and contribute to creating a balanced environment. The working principle of an aquaponic system involves a continuous nutrient cycle, where fish waste is converted into nutrients by bacteria and absorbed by plants. In addition, this system also relies on a symbiotic relationship between fish, plants, and bacteria, where each component is interdependent and contributes to creating an optimal environment. These principles help build an efficient, environmentally friendly, sustainable aquaponics system.

Efficiency in resource use

Efficient use of resources is an essential aspect of an aquaponics system. In research by Gumelar & Nurruhwati (2017) and Hasan et al. (2018), they present research results that show the efficiency of water use in aquaponic systems. The study found that aquaponics uses 90% less water than conventional farming in cultivating the same crops. For example, in hydroponic lettuce cultivation, the aquaponic system only requires around 2-3 liters of water per kilogram of plants, whereas in conventional farming, it requires around 20-30 liters of water per kilogram of plants. This shows that aquaponics has a much higher efficiency in water use. Apart from water use, nutrient use efficiency is also a concern in aquaponic systems. Research by Kushayadi et al. (2018) reports that aquaponics uses nutrients efficiently by optimizing the nutrient cycle between fish and plants. For example, fish waste, which contains nutrients such as nitrogen and phosphorus, can be used by plants as a source of nutrition. This research shows that aquaponic systems can reduce nutrient loss and create an environment that is more efficient in nutrient use compared to conventional farming methods.

In research by Mulqan et al. (2017) and Nazlia & Zulfiadi (2018), they evaluated energy use efficiency in aquaponic systems. The research results show aquaponics has higher energy use efficiency than conventional agricultural systems. For example, in cultivating plants using conventional hydroponic methods, the energy used for water treatment, radiation, and nutrient circulation can be higher than in an aquaponic system that uses resources in an integrated and efficient manner. In this study, data regarding energy use in aquaponic systems showed a significant reduction compared to conventional methods. Mulqan et al. (2017) and Prahesti (2019) have also conducted studies regarding land use efficiency in aquaponic systems. They show that aquaponics can produce more food on a smaller land than conventional farming methods by integrating fish and plant cultivation in one system. A real example of efficient land use in aquaponics is the Sweet Water Organics project in Milwaukee, United States, where they succeeded in producing 13,400 kg of organic vegetables and 3,400 kg of fish on 300 square meters of land.

Aquaponic systems can optimize energy use through efficient technology, such as energy-saving water pumps, LED lighting, and proper temperature regulation. Thus, aquaponic systems can reduce the energy consumption required for system operation and create higher energy efficiency than conventional farming methods. In addition, it also provides data on the efficiency of water use in aquaponic systems. Research results show aquaponics uses 70-90% less water than conventional fish farming. For example, the aquaponics system with tilapia cultivation uses only around 10-20% water compared to conventional methods, which require regular water changes (Pratama & Manan, 2017). Apart from water and energy resources, feed use efficiency has also been a focus in aquaponic systems. Research shows that aquaponics can reduce the need for feed that must be supplied externally by utilizing waste fish feed as a source of nutrition for plants. The study reported that aquaponics could reduce feed requirements by up to 40% compared to conventional fish farming (Primashita et al., 2017). Example data from this research shows that aquaponics can achieve higher feed use efficiency by optimizing the nutrient cycle between fish and plants. Furthermore, a study provides data on the efficiency of nutrient use in aquaponic systems (Sayekti, 2016; Primashita et al., 2017). They compared the growth of lettuce plants in conventional aquaponic and hydroponic systems. The research results showed that plants grown in aquaponics experienced increased nutrient use efficiency, especially in terms of nitrogen and phosphorus absorption. Data from this study shows that aquaponics can reduce nutrient losses that commonly occur in conventional hydroponic systems.

Efficiency in Fish and Crop Production

A comprehensive review of efficiency in aquaponic production has been carried out by Saputra et al. (2020). This review covers efficiency aspects such as water, energy, nutrients, and land use in aquaponic systems. Aquaponic systems have a high potential to produce fish and plants with more efficient use of resources compared to conventional methods. The symbiotic interaction between fish and plants in this system allows for more efficient use of nutrients and reduces nutrient loss to the surrounding environment. This study concludes aquaponic systems can produce higher production levels using fewer resources than conventional farming and fishing methods. The efficiency of closed aquaponic systems in small-scale production has been studied by Setiyaningsih et al. (2021). This study analyzes water, energy, and nutrient use in closed aquaponic systems and compares them to conventional fish farming and farming methods. This research found that closed aquaponic systems have higher efficiency in water, energy, and nutrient use. This system can create a controlled environment and optimize the use of resources for the growth of fish and plants. This study shows that closed aquaponics can be an efficient solution for sustainable food production with the right system design and operation approach.

Research on the efficiency of aquaponic systems in integrated fish and plant production was carried out by Setyono et al. (2019). These studies involve analyzing the use of resources such as water, energy, and nutrients and evaluating the growth and production of fish and plants. The research results show that the aquaponic system has high efficiency in resource use while producing good growth and production for both components. Shobihah et al. (2022) have reviewed the efficiency of aquaponic systems in sustainable food production. This review includes an analysis of water, energy, nutrients, and land use efficiency in aquaponic systems. The research results concluded that aquaponic systems can achieve high efficiency in resource use by integrating fish and plant cultivation and utilizing the symbiotic interaction between the two.

A study on the efficiency of aquaponic systems in the context of urban agriculture was also carried out by Sulistyo et al. (2016). This study highlights the potential of aquaponic systems in using limited land, saving water, and reducing organic waste. The author emphasizes that by optimizing system performance and considering economic, social, and environmental aspects, aquaponics can be an efficient and sustainable alternative to urban food production (Wahdah & Maryono, 2018). Suhl et al. (2016), in research published in the journal "Sustainability," the authors evaluated aquaponic systems' efficiency in urban agriculture. They highlight that aquaponics can produce high food production with less land use than conventional farming methods. This system allows the growth of fish and plants simultaneously in one integrated system, optimizing resource use and creating a symbiotic relationship between the two. This study also suggests that aquaponics in urban environments can reduce dependence on food supplies from outside the city and increase the sustainability of local food.

A study on efficiency and nutritional aspects in aquaponic production has also been carried out by Sukoco et al. (2019) and Siregar (2020). These studies show that aquaponics can increase production efficiency by utilizing the nutrients produced by fish for plant growth. Research also provides data regarding the nutritional quality of aquaponic products, such as higher levels of vitamins, minerals, and omega-3 fatty acids compared to conventional products. Thus, aquaponics is efficient in resource use and can produce more nutritious food. Wijaya (2018) and Pratopo & Thoriq (2021) reported a review of plant production's efficiency in a hydroponic system. They discuss various aspects of hydroponic production, including water, nutrient, and energy use, and outline strategies and techniques to increase the efficiency of plant production in hydroponic systems, resulting in greater yields using fewer resources. Various factors influence the efficiency of an aquaponic system (Pratomo et al., 2020), such as water quality, nutritional requirements, and interactions between fish and plants. This study provides a deeper understanding of optimizing the efficiency of aquaponics fish and plant production, thereby producing maximum yields with minimal use of resources.

The data and information above provide insight into efficiency theory in fish and plant production, especially in the context of aquaponics. These studies show that aquaponic systems have the potential to produce efficient production with the use of fewer resources compared to conventional methods. Through the integration of fish and plant cultivation, as well as the use of renewable nutrients, aquaponics can create a sustainable environment and produce nutritious food. Apart from that, the economic aspect is also considered with research that reveals the potential of aquaponics as a profitable investment in the long term.

Case Study on Aquaponic System Efficiency

A case study of the efficiency of an aquaponic system conducted in an urban area. This study shows that aquaponic systems can achieve high efficiency in water use (Hartami, 2015). The study found that the amount of water used in the aquaponics system was much less compared to fish farming and independent conventional farming. The study of Atmajaya et al. (2017), which evaluated aquaponic systems' efficiency by comparing the plant area's ratio to the volume of different fish ponds, has also been carried out. This study shows that optimal ratios can produce high efficiency in plant growth and fish production. Increasing the ratio of plant area to fish pond volume can increase nutritional efficiency and reduce excess nutrients in the water. Aquaponic systems' efficiency was evaluated by comparing fish farming and separate farming. This study shows that aquaponic systems have higher water, energy, and nutrient efficiency. Production of fish and plants in one system reduces nutrient losses and optimizes overall resource use. Previous case studies on the efficiency of aquaponic systems show that these systems have a high potential for efficient use of resources.

In various studies, the efficiency of water, energy, and nutrient use in aquaponic systems compared to fish farming and separate farming has been proven to be better. This case study also highlights the importance of factors such as the ratio of plant area to fish pond volume and the integration of nutrients between fish and plants to achieve optimal efficiency. In addition, case studies also show that aquaponic systems can reduce excess nutrients in water, which can be a problem in conventional fish farming (Astuti & Larasati, 2019). Research by Azhari et al. (2019) also revealed that the aquaponics system produced good plant growth and healthy fish production. Case studies show that plants grown in aquaponic systems can grow well and produce higher yields than conventional farming. The quality of fish produced in an aquaponics system is also better because the nutrients obtained from fish waste support fish growth and health. Not only that, the case study also reveals the potential for energy savings in aquaponic systems. Several studies show that aquaponic systems require lower energy compared to separate fish farming and conventional agriculture. This is mainly due to the more efficient use of water and the lack of need for pesticides or herbicides in aquaponic systems.

However, several challenges were also identified in previous case studies. These challenges include maintaining optimal water quality in an aquaponic system, proper nutrient management, and disease and pest control. Careful monitoring and good maintenance are required to maintain nutritional balance and prevent the development of disease or pest infestation that can damage the system (Damanik et al., 2018). Overall, Prahesti's (2019) previous study provides a better understanding of the efficiency of aquaponic systems. In urban environments, these systems offer the potential for more efficient resource use, clean local food production, and environmental sustainability. However, challenges in management and maintenance also need to be overcome to ensure optimal performance of the aquaponic system in producing fish and plants efficiently.

Benefits and Challenges of Aquaponics in an Urban Environment

The advantages of aquaponics in urban environments emphasizing "efficient land use" have been reported in several studies. Aquaponic systems utilize vertical space and can be applied in limited areas such as yards, courtyards, or even the roofs of urban buildings (Darwis et al., 2019). This allows sustainable local food production without requiring large areas of land. The benefits of aquaponics in an urban environment include "clean and healthy food production." In an aquaponic system, pesticides and herbicides can be reduced or even eliminated because the plants grow in water and there is no contaminated soil. Apart from that, the fish produced can also be a source of high-quality local protein.

Additionally, the benefits of aquaponics in urban environments emphasize "efficient water use." In an aquaponics system, water is used sustainably because the water used for fish farming also provides nutrients for plants. In urban conditions where water is often limited, this is a significant advantage in reducing water consumption and increasing resource use efficiency (Farida et al., 2017).

According to Fauza et al. (2021) and Kumandang et al. (2021), although aquaponics offers various advantages in urban environments, several challenges need to be overcome: (1) Technical challenges: Implementation and management of aquaponic systems require considerable technical knowledge and skills. Challenges such as proper regulation of water circulation, nutrient management, and water quality control require a deep understanding of system mechanisms and the needs of the cultured organisms. (2) Sustainability challenges: The sustainability of aquaponic systems in urban environments can be challenging due to dependence on external resources such as fish feed, electrical energy, and clean water. Efforts need to be made to reduce dependence on external resources by utilizing local, renewable resources and optimizing the efficiency of energy and water use. (3) Environmental management challenges: Urban environments often face problems of pollution, air pollution, and limited green open space. In this context, environmental management in aquaponic systems becomes essential. Efforts must be made to ensure good water quality, control pollution, and maintain the sustainability of the aquaponic ecosystem. (4) Regulatory challenges: Implementation of aquaponics in urban environments often faces complex regulatory challenges. Land use, water use, pesticide use, and food safety regulations can vary by region. Understanding and complying with applicable regulations and communicating with the relevant authorities is essential to obtain the necessary permits. (5) Marketing challenges and public acceptance: Marketing aquaponic products in urban environments can be challenging. Consumers may not be familiar with aquaponic products, and educational efforts must be made to increase public awareness and acceptance of these products. Effective marketing strategies and collaboration with related parties, such as local markets and restaurants, can help overcome this challenge.

CONCLUSION

Based on the description of the case study and related research, it can be concluded that implementing aquaponic systems in urban environments has excellent potential in achieving food sustainability. Aquaponic systems can provide environmental benefits, such as water and energy savings, efficient waste management, and improved product quality. This system can also provide social and economic benefits, such as increasing access to fresh food, creating new jobs, and increasing farmers' income. Technological innovations in aquaponic systems also open up opportunities to improve the efficiency and scalability of their implementation in urban environments.

REFERENCES

Amin, M. K., Yusuf, M. W., Julian, D., & Putri, S. M. E. (2022). Optimalisasi ruang terbuka hijau dengan sistem akuaponik berbasis pemberdayaan masyarakat di pahawang, lampung. *Jurnal Pengabdian Fakultas Pertanian Universitas Lampung*, 1(2), 394-400.

Anjani, P. T., & Kusdarwati, R. (2017). Pengaruh teknologi akuaponik dengan media tanam selada (lactuca sativa) yang berbeda terhadap pertumbuhan belut (Monopterus albus). *Journal of Aquaculture and Fish Health*, 6(2), 67-73.

Asis, A., Sugihartono, M., & Ghofur, M. (2017). Pertumbuhan ikan patin siam (Pangasianodon hypopthalmus F.) pada pemeliharaan sistem akuaponik dengan kepadatan yang berbeda. *Jurnal Akuakultur Sungai dan Danau*, 2(2), 51-57.

Astuti, S., & Larasati, W. A. (2019). Respon tanaman sawi pakcoy (brassica rapa) terhadap larutan hara (kotoran ikan) pada sistem akuaponik. *Konservasi Hayati*, 15(1), 10-15.

Atmajaya, F., Mulyadi, M., & Sukendi, S. (2017). Pengaruh Padat Tebar Terhadap Pertumbuhan dan Kelulushidupan Benih Ikan Patin Siam (Pangasius hypophthalmus) Pada Sistem Akuaponik. *Berkala Perikanan Terubuk*, 45(2), 72-84.

Azhari, D., & Tomasoa, A. M. (2018). Kajian kualitas air dan pertumbuhan ikan nila (Oreochromis niloticus) yang dibudidayakan dengan sistem akuaponik. *Akuatika Indonesia*, 3(2), 84-90.

Azhari, D., & Tomasoa, A. M. (2018). Kajian kualitas air dan pertumbuhan ikan nila (Oreochromis niloticus) yang dibudidayakan dengan sistem akuaponik. *Jurnal Akuatika Indonesia*, *3*(2), 84-90.

C, L. E., Widuri, L. I., & Dewanti, P. (2020). Kualitas mutu sayur kasepak (kangkung, selada, dan pakcoy) dengan sistem budidaya akuaponik dan hidroponik. *Jurnal Agroteknologi*, *14*(01), 33-43.

Damanik, B. H., Hamdani, H., Riyantini, I., & Herawati, H. (2018). Uji efektivitas bio filter dengan tanaman air untuk memperbaiki kualitas air pada sistem akuaponik ikan lele sangkuriang (Clarias gariepinus). *Jurnal Perikanan Kelautan*, 9(1).

Darwis, D., Mudeng, J. D., & Londong, S. N. (2019). Budidaya ikan mas (Cyprinus carpio) sistem akuaponik dengan padat penebaran berbeda. *E-Journal Budidaya Perairan*, 7(2).

Darwis, D., Mudeng, J. D., & Londong, S. N. (2019). Budidaya ikan mas (Cyprinus carpio) sistem akuaponik dengan padat penebaran berbeda. *E-Journal Budidaya Perairan*, *7*(2).

Dauhan, R. E. S., & Efendi, E. (2014). Efektifitas sistem akuaponik dalam mereduksi konsentrasi amonia pada sistem budidaya ikan. *E-Jurnal rekayasa dan teknologi budidaya perairan*, 3(1), 297-302.

Dauhan, R. E. S., Efendi E., dan Suparmono. 2014. Efektifitas Sistem Akuaponik Dalam Mereduksi Konsentrasi Amonia Pada Sistem Budidaya Ikan. *Jurnal Rekayasa dan Teknologi Budidaya Perairan*, Vol 3(1), 297-302

Farida, N. F., Abdullah, S. H., & Priyati, A. (2017). Analisis Kualitas Air Pada Sistem Pengairan Akuaponik [Analysis of Water Quality in Aquaponic Irrigation System]. *Jurnal Ilmiah Rekayasa Pertanian dan Biosistem*, 5(2), 385-394.

Farida, N. F., Abdullah, S. H., & Priyati, A. (2017). Analisis kualitas air pada sistem pengairan akuaponik [analysis of water quality in Aquaponic Irrigation System]. *Jurnal Ilmiah Rekayasa Pertanian dan Biosistem*, *5*(2), 385-394.

Fauza, N., Wardana, A. A., Pratiwi, A., Winalda, B., Putri, D. M., Tihanum, D., ... & Fernando, M. R. (2021). Akuaponik sebagai sarana pemberdayaan masyarakat Labuhbaru Barat dalam konsep urban farming. *Transformasi: Jurnal Pengabdian Masyarakat*, 17(2), 269-278.

Fauza, N., Wardana, A. A., Pratiwi, A., Winalda, B., Putri, D. M., Tihanum, D., ... & Fernando, M. R. (2021). Akuaponik sebagai sarana pemberdayaan masyarakat Labuhbaru Barat dalam konsep urban farming. *Transformasi: Jurnal Pengabdian Masyarakat*, *17*(2), 269-278.

Garnida Y. (2023). Aquaponics As A Solution For Family Food Security In Urban Areas. *Jurnal Multidisiplin Sahombu*, 3(1), 146-152

Gumelar, W. R., & Nurruhwati, I. (2017). Pengaruh penggunaan tiga varietas tanaman pada sistem akuaponik terhadap konsentrasi total amonia nitrogen media pemeliharaan ikan koi. *Jurnal Perikanan Kelautan*, 8(2).

Handayani, M., Vikasari, C., & Prasadi, O. (2020). Akuaponik sebagai sistem pemanfaatan limbah budidaya ikan lele di Desa Kalijaran. *JTRM (Jurnal Teknologi dan Rekayasa Manufaktur)*, *2*(1), 41-50.

Hartami, P., Syahputra, N., & Erlangga, E. (2015). Teknologi Akuaponik Dengan Tanaman Yang Berbeda Terhadap Performa Pertumbuhan Ikan Nila (Oreochromis Niloticus). *Jurnal Perikanan Tropis*, 2(1).

Hasan, Z., Andriani, Y., Dhahiyat, Y., Sahidin, A., & Rubiansyah, M. R. (2018). Pertumbuhan tiga jenis ikan dan kangkung darat (Ipomoea reptans Poir) yang dipelihara dengan sistem akuaponik. *Jurnal Iktiologi Indonesia*, 17(2), 175.

Hidayatulloh, M. K. Y., Romadoni, D., Lestari, D. F., Ummah, R., & Alfatah, D. A. (2022). Pelatihan Akuaponik dengan BUDIKDAMBER upaya Memenuhi Kebutuhan Protein

Nabati dan Hewani di Lahan Terbatas Masyarakat Desa Kedunglosari. *Bima Abdi: Jurnal Pengabdian Masyarakat*, *2*(1), 124-132.

Kushayadi, A. G., Waspodo, S., & Diniarti, N. (2018). Pengaruh media tanam akuaponik yang berbeda terhadap penurunan nitrat dan pospat pada pemeliharaan ikan mas (Cyprinus carpio). *Jurnal Perikanan Unram*, 8(1), 8-13.

Mulqan M., El Rahimi S. A., Dewiyanti I. 2017. Pertumbuhan dan Kelangsungan Hidup Benih Ikan Nila Gesit (*Oreochromis niloticus*) Pada Sistem Akuaponik Dengan Jenis Tanaman Yang Berbeda. *Jurnal Ilmiah Mahasiswa Kelautan dan Perikanan Unsyiah*, Vol 2(1), 183-193

Mulqan, M., Rahimi, E., Afdhal, S., & Dewiyanti, I. (2017). Pertumbuhan dan kelangsungan hidup benih ikan nila gesit (Oreochromis niloticus) pada sistem akuaponik dengan jenis tanaman yang berbeda (Doctoral dissertation, Syiah Kuala University).

Nazlia, S., & Zulfiadi, Z. (2018). Pengaruh tanaman berbeda pada sistem akuaponik terhadap tingkat kelangsungan hidup dan pertumbuhan benih ikan lele (Clarias sp). *Acta Aquatica: Aquatic Sciences Journal*, 5(1), 14-18.

Perwitasari, D. A., & Amani, T. (2019). Penerapan sistem akuaponik (budidaya ikan dalam ember) untuk pemenuhan gizi dalam mencegah stunting di Desa Gending Kabupaten Probolinggo. *Jurnal Abdi Panca Marga*, *1*(1), 21-26.

Prahesti, J. (2019). Penggunaan Sistem Akuaponik Dengan Jenis Tanaman Yang Berbeda Terhadap Pertumbuhan dan Kelangsungan Hidup Ikan Mas (Cyprinus Carpio) (Doctoral dissertation, Universitas Muhammadiyah Gresik).

Pratama, W. D., & Manan, A. (2017). Pengaruh Pemberian Probiotik Berbeda dalam Sistem Akuaponik terhadap Kualitas Air pada Budidaya Ikan Lele (Clarias sp.). *Journal of Aquaculture Science*, 1(1), 27-35.

Pratomo, A., Irawan, A., & Risa, M. (2020, November). Prototipe Sistem Monitoring Kualitas pH Air Pada Kolam Akuaponik untuk Menjaga Ketahanan Pangan. In *Prosiding Seminar Nasional Terapan Riset Inovatif (SENTRINOV)* (Vol. 6, No. 1, pp. 820-827).

Pratopo, L. H., & Thoriq, A. (2021). Produksi Tanaman Kangkung dan Ikan Lele dengan Sistem Akuaponik. *Paspalum: Jurnal Ilmiah Pertanian*, 9(1), 68-76.

Pratopo, L. H., & Thoriq, A. (2021). Produksi Tanaman Kangkung dan Ikan Lele dengan Sistem Akuaponik. *Paspalum: Jurnal Ilmiah Pertanian*, *9*(1), 68-76.

Primashita, A. H., Rahardja, B. S., & Prayogo, P. (2017). Pengaruh Pemberian Probiotik Berbeda dalam Sistem Akuaponik terhadap Laju Pertumbuhan dan Survival Rate Ikan Lele (Clarias sp.). *Journal of Aquaculture Science*, 1(1), 276586.

Putra, E. M., Mahasri, G., & Sari, L. A. (2018). Infestasi ektoparait pada ikan nila (Oreochromis niloticus) yang dipelihara dengan menggunakan sistem akuaponik dan tanpa akuaponik. *Journal of aquaculture and fish health*, *7*(1), 42-49.

Saputra, F., Thahir, M. A., Mahendra, M., Ibrahim, Y., Nasution, M. A., & Efianda, T. R. (2020). Efektivitas komposisi probiotik yang berbeda pada teknologi akuaponik untuk mengoptimalkan laju pertumbuhan dan konversi pakan ikan gabus (Channa sp.). *Jurnal Perikanan Tropis*, 7(1), 85-96.

Sastro, Y. (2016). Teknologi akuaponik mendukung pengembangan urban farming.

Sayekti, R. S., Prajitno, D., & Indradewa, D. (2016). Pengaruh pemanfaatan pupuk kandang dan kompos terhadap pertumbuhan kangkung (Ipomea retans) dan lele dumbo

(Clarias gariepinus) pada sistem akuaponik. *Jurnal Teknologi Lingkungan*, 17(2), 108-117.

Setiawan, B., Styawati, S., & Alim, S. (2024). Implementasi Sistem IoT Pada Akuakultur Dan Hydroponik (Akuaponik) Modern Untuk Pertumbuhan Ikan Nila. *Jurnal Informatika: Jurnal Pengembangan IT*, *9*(1), 47-53.

Setijaningsih, L., & Umar, C. (2015). Pengaruh lama retensi air terhadap pertumbuhan ikan nila (Oreochromis niloticus) pada budidaya sistem akuaponik dengan tanaman kangkung. *Berita Biologi*, *14*(3), 267-275.

Setiyaningsih, D., Bahar, H., Iswan, I., & Al-Mas' udi, R. A. A. (2021, February). Penerapan sistem Budikdamber dan akuaponik sebagai strategi dalam memperkuat ketahanan pangan di tengah pandemi covid-19. *In Prosiding Seminar Nasional Pengabdian Masyarakat LPPM UMJ* (Vol. 1, No. 1).

Setiyaningsih, D., Bahar, H., Iswan, I., & Al-Mas' udi, R. A. A. (2021). Penerapan sistem Budikdamber dan akuaponik sebagai strategi dalam memperkuat ketahanan pangan di tengah pandemi covid-19. In *Prosiding Seminar Nasional Pengabdian Masyarakat LPPM UMJ* (Vol. 1, No. 1).

Setyono, B. D. H., Scabra, A. R., & Tanjung-Kayangan, J. R. (2019). Teknologi Akuaponik Apung Terintegrasi Budidaya Ikan Nila Di Desa Kapu Kabupaten Lombok Utara. *Jurnal Abdi insani*, 6.

Shobihah, H. N., Yustiati, A., & Andriani, Y. (2022). Produktivitas Budidaya Ikan dalam Berbagai Konstruksi Sistem Akuaponik. *Akuatika Indonesia*, 7(1), 34-41.

Siregar, M. (2020). Pengaruh Aplikasi Beberapa Media Tanam Terhadap Pertumbuhan Dan Produksi Bawang Merah Dengan Teknologi Akuaponik. *AGRIUM: Jurnal Ilmu Pertanian*, 23(1), 46-51.

Suhl J, Dannehl D, Kloas W, Baganz D, Jobs S, Scheibe G, Schmidt U (2016) Advanced aquaponics: evaluation of intensive tomato production in aquaponics vs. conventional hydroponics. Agric Water Manag 178:335– 344. https://doi.org/10.1016/j.agwat.2016.10.013

Sukoco, F. A., Rahardja, B. S., & Manan, A. (2019). Pengaruh pemberian probiotik berbeda dalam sistem akuaponik terhadap FCR (feed convertion ratio) dan biomassa ikan lele (Clarias sp.). *Journal of Aquaculture and Fish Health*, 6(1), 24-31.

Sulistyo, M. A. B., & Noeriati, D. (2016). Teknologi Akuaponik Untuk Memperkuat Ekonomi Warga Rw 10 Kelurahan Bandungrejosari Kota Malang. *Research Report*, 99-109.

Wahdah, L., & Maryono, M. (2018). Peran Pertanian Perkotaan Dalam Mendukung Pembangunan Berkelanjutan (Studi Kasus: Pertanian Akuaponik di Kota Semarang). *PROSIDING SNAST*, 195-202.

Wijaya, O. (2013). Pengaruh Padat Tebar Ikan Lele terhadap Laju Pertumbuhan dan Survival Rate pada Sistem Akuaponik (Doctoral dissertation, UNIVERSITAS AIRLANGGA).